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[Translation from German]

PCT/EP 2004/ 051,066

06 August 2004

[emblem]

AUSTRIAN PATENT OFFICE

A-1200 Vienna, Dresdner Strasse 87

EP/51066

Clerical fee € 16.00

Publication fee € 65.00

Serial number A 1072/2003

REC'D 13 AUG 2004

WIPO PCT

The Austrian Patent Office certifies that on **11 July 2003**

the firm of LUMITECH Holding GmbH

in A-8380 Jennersdorf, Technologiepark 10

(Burgenland),

submitted a patent application relating to

"LED and LED light source"

and that the appended specification and drawings correspond to the original specification and drawings submitted together with
this patent application.

Austrian Patent Office

Vienna, 10 July 2004

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	COMPLIANCE WITH RULE 17.1(a) OR (b)

16Se/40 460 [Perforated:] 023,513

A1072/2003 (51) IPC [Stamp:] **Original**

(11) No.

AT PATENT SPECIFICATION

(When filing an application, please complete only the boxed fields. Boxes in bold must be completed.)

(73)	Patent Owner(s): LUMITECH Holding GmbH Jennersdorf (AT)
(54)	Title of the Application: LED and LED light source
(61)	Addition to Patent No.:
(66)	Conversion of Utility Model
(62)	Separate Application from (Division): A
(30)	Priority (Priorities):
(72)	Inventor:

(21) (22) Application Date, Serial No.:

2003 07 11, A /

(60) Dependence:

(42) Start of term of patent:

Longest possible duration:

(45) Date of issue:

===

(56) Printed sources considered in evaluating patentability:

The present invention relates to an LED, in which at least one LED die is arranged on an LED PCB with a die attach, and the LED PCB has on the side opposite to the LED die electrical rear side contacts, which if appropriate are plug-in contacts. It further relates to an LED light source having one or more LEDs of the kind mentioned at the beginning, arranged on a board or on a plug, wherein the board has contact surfaces or the plug has contacts, with which the LEDs are contacted. Lastly, it also relates to an LED light source having one or more LEDs arranged on a board or on a plug, wherein the board has contact surfaces and the plug has contacts, with which the LEDs are contacted.

LED light sources normally have the following structure:

The LED die is applied to a contact surface (e.g. conductor path) of an LED PCB by means of a die attach (PCB = printed circuit board; the term die attach includes both a die adhesive connection and a solder connection). Together with the rear side contacts of the LED PCB, this arrangement represents a self-contained LED lamp. This LED lamp is assembled onto a board by means of a mounting technology (e.g. SMT), which board is then optionally connected with a cooling body. Optionally, the lamp may be fixed and contacted in a lamp socket. Instead of on a board, the LED may alternatively be assembled on a plug.

In order to realize LED applications having high brightness, ever stronger high-power LEDs are put into use, already even with an operating power of more than one W_{el}. The chip area of these LEDs is at the present time in the region of

1 mm^2. The trend is that in the future the operating power per LED will further increase, which on the one hand will be achieved by means of larger semiconductors and, on the other, by means of higher current densities. In particular, the latter parameter has the effect that the power density of LEDs of at present maximally 1-2 W_{el}/mm^2 will in the future increase to over 4 W_{el}/mm^2.

However, appropriate arrangements have to be provided for discharge of the heat loss, to allow the heat to be sufficiently discharged from the semiconductor.

Too great heating during operation of the LED leads to component destruction. For this reason, during operation of the LED, it must be ensured that the temperature at the barrier layer of the p-n junction in the LED does not rise above typically 130° C. This may occur during operation of the LED, insofar as only a part of the electrical power absorbed by the component is converted to light, while the other part is converted to heat. (At the present time, the power efficiency of LEDs is less than 10%.) The operating parameters of LEDs are therefore to be selected depending upon manner of assembly, installation and environmental conditions, such that the barrier layer temperature always remains below 130°C.

In the subject invention, arrangements are presented which can discharge the heat loss of LEDs with such efficiency that power densities of over 2 W_{el}/mm^2 can be discharged.

In order to discharge the heat loss efficiently, the thermal resistance of the arrangement must be optimized. If the heat can be transferred to the LED carrier

without a great temperature difference, the barrier layer remains below the maximum permissible temperature. The significant physical parameter is thus the thermal resistance, measured in K/W.

Arrangements and structures such as are at the present time state of the art for high-power LEDs have in optimized arrangements typically a thermal resistance of more than 20 K/W (interface junction to LED carrier material).This means that the temperature difference between the LED carrier and the active zone of the LED - in operation at 5 W_{el} – is more than 100 K. Starting from a maximum permissible barrier layer temperature for long-term applications of 130°C, this means that utilization is not possible at temperatures above 30°C and thus this LED is unsuitable for many technical applications (automobiles, transport).

The object of the present invention is to procure an LED or an LED light source of the kind mentioned at the beginning, in which the thermal resistance is less than that in accordance with the prior art.

This object is accomplished in accordance with the invention by means of an LED of the kind mentioned at the beginning in that the rear side contacts cover at least half the area, preferably the entire area apart from the necessary exceptions, of the LED PCB. The necessary exceptions are e.g. the necessary spacings for electrical insulation of conductor paths at different electrical potential.

Previously, the contact surfaces were always dimensioned only with regard to the electrical resistance and thus were provided, in comparison to the invention, with

less cross-sectional area. In accordance with the invention, however, these contact areas are to be as large as possible, owing to which the thermal resistance is correspondingly reduced. There it is favorable that the thermal and electrical line is carried perpendicularly through the carrier material. In this way, a structure which is as compact as possible (without spatially extensive lateral side contacts) can be realized.

It is favorable if the rear side contacts are thermally, and if appropriate electrically, connected with the contact surfaces on the side towards the LED die, to the lateral side of the LED PCB. This not only improves the thermal resistance, but also the soldering and contacting characteristics.

In the case of insulating boards (e.g. in the case of organic LED PCBs), the LED die is normally applied to a conductor path. In the case of metal core boards, however, the conductor paths must be insulated with respect to the metal core. This insulation layer naturally increases the thermal resistance. For this reason, it is expedient that – when the LED PCB is a metal core board – the LED die is applied directly on the metal core.

Alternatively to this, in the case of a metal core board, an electrically non-linear insulation material may be arranged between the conductor paths and the metal core. Since LEDs are operated at relatively low voltage, the insulation material may in principle be provided in a very thin layer, without having to fear a breakdown in operation. However, upon handling a higher voltage may occur, e.g. by means of static charge, which in the case of thin insulation material can lead to a breakdown and thus could make the LED unusable. This is avoided

with an electrically non-linear insulation material because above a certain voltage the latter is conductive. As a result, static electricity is discharged, without producing damage. Thus, with an electrically non-linear insulation material it is possible to make do with a lesser thickness, which reduces the thermal resistance correspondingly.

When the LED is mounted face down on the LED die, the light yield is higher, because then no light is shaded by the otherwise necessary bonding wires.

In the case of an LED light source of the kind first mentioned at the beginning, the above-mentioned object is accomplished in accordance with the invention in that the rear side contacts of the LED on at least half the area of the LED PCB, preferably over the entire area apart from the necessary exceptions, are soldered with the contact areas or the contacts.

In an LED light source of the second kind mentioned at the beginning, in accordance with the invention the LED dies are pasted with a die attach are pasted directly onto the board or onto the plug.

In accordance with this embodiment, the LEDs thus no longer form self-contained mechanical parts, but rather the board (or the plug) simultaneously serves as LED PCB. Hence the thermal resistance of the LED PCB and of the solder pad (or however contact with the board was previously effected) is eliminated.

The same inventive idea is also put into practice here: the thermal line is carried perpendicularly through the carrier material, specifically over the entire cross-sectional area of the LED die. In this way – as mentioned – as compact as

possible a structure (without spatially extensive lateral side contacts) can be realized.

In this case, too, it is expedient that – when the board is a metal core plate – the LED dies be applied directly onto the metal core or that the electrically non-linear insulation material be arranged between the conductor paths and the metal core. It is favorable if a cooling body is arranged on the rear side of the board. In this way, heat is discharged from the board, without space on the forward side of the board being necessary for this purpose. The cooling body may be any metallic functional body (e.g. a housing) and may be connected thermally with the board by any desired connection technology.

In this case it is further favorable if the board and/or the LED PCB have through-contacts for increasing the thermal conductivity, where the through-contacts preferably have a diameter of less than 100 µm. This applies in particular to boards of organic material, the thermal conductivity of which is poor per se.

The invention will be explained in more detail with reference to the accompanying drawings, wherein Fig. 1 shows a first embodiment of an LED light source in accordance with the invention; Fig. 2, a modification of the LED illustrated in Fig. 1; Fig. 3, an additional modification of the LED illustrated in Fig. 1; Fig. 4, a second embodiment of an LED light source in accordance with the invention; and Fig. 5, a modification of this LED light source, shown without cooling body.

In accordance with Fig. 1, an LED die 3 ($R_{th,\ LED\ die}$) is applied to a contact surface (e.g. conductor path 5) of an LED PCB 6 ($R_{th,\ LED\ PCB}$) by means of a

die adhesive 4 ($R_{th,\ die\ adhesive}$). The LED die 3 in Fig. 1 is mounted face up and connected via bonding wires 2 with the contact surfaces (conductor path 5). Alternatively thereto, the LED die can also be arranged in a face-down mounting directly on the LED PCB or it can be attached face down to a die carrier, and the latter then arranged on the LED PCB. Together with the rear side contacts 7 ($R_{th,\ solder\ pads}$) of the LED PCB 6 this arrangement represents a self-contained LED lamp. For further processing, this LED lamp can be assembled by means of a mounting technology (e.g. SMT) on a board 9 ($R_{th,\ board}$), which is then optionally connected with a cooling body 11, e.g. via a solder area 10 ($R_{th,\ solder\ area}$).

The LED die 3 is normally cast in a material 1 having appropriate optical characteristics. The LED die may alternatively – as is known – be placed in a reflector. Of course, a plurality of LED dies can also be cast together or put in place in a reflector.

The typical thermal resistance of the overall arrangement in accordance with Fig. 1 is made up as follows:

$R_{th} = R_{th,\ LED\ die}$ (4 K/W) + $R_{th,\ die\ adhesive}$ (2 K/W) + $R_{th,\ LED\ PCB}$ (5 K/W) + $R_{th,\ solder\ pads}$ (3 K/W) + $R_{th,\ board}$ (2 K/W) + $R_{th,\ solder\ area}$ (2 K/W) = **18** K/W.

In order to improve the soldering characteristics and the heat discharge via the rear side, it is expedient (in particular in the case of ceramic boards and organic PCBs) to provide lateral side contact layers 12 (see Fig. 2) which

thermally, and if applicable electrically, connect the upper side of the PCB with the underside of the PCB. The soldering characteristics of the LED arrangement can be improved both in the case of manual soldering and also in automatic equipment (SMT wave or reflow soldering) by means of better solder engagement and better thermal distribution. Further, the solder point can be better judged from the exterior.

In accordance with Fig. 3, the LED die 3 is not placed on a conductor path 5 but directly on the core of the LED PCB 6. This is advisable particularly in the case of metal core boards, because here a thin insulation layer is needed between the conductor paths 5 and the metal core in order to electrically insulate the conductor paths 5. This insulation layer also increases the thermal resistance, so that the direct arrangement of the LED die 3 on the metal core of the LED PCB 6 has a smaller thermal resistance.

In accordance with Fig. 4, the LEDs no longer form self-contained mechanical components, but the LED dies 3 are pasted directly on the board 9. The LED die 3 ($R_{th,\ LED\ die}$) is thus applied to a contact surface (e.g. conductor path 5) of the board 9 ($R_{th,\ board}$) by means of a die adhesive 4 ($R_{th,\ die\ adhesive}$). The rear side of the board 9 is thermally coupled by a solder area 10 ($R_{th,\ solder\ area}$) to a cooling body 11. Contacting of the LED die takes place via contact points 13 on the forward side of the board 9.

The LED die is normally cast in a material 1 having appropriate optical characteristics. The LED die may alternatively – as is known – be placed in a reflector. In this embodiment, a plurality of LED dies may also be cast together or

placed in a reflector.

The typical thermal resistance of the overall arrangement in accordance with Fig. 4 is made up as follows:

$R_{th} = R_{th, \text{LED die}}$ (4 K/W) + $R_{th, \text{die adhesive}}$ (2 K/W) + $R_{th, \text{board}}$ (5 K/W) + $R_{th, \text{solder area}}$ (2 K/W) = **13** K/W.

In accordance with Fig. 5, the LED die 3 – analogous to in Fig. 3 – is not set on a conductor path 5, but directly on the core of the LED PCB 6. This again is advisable particularly in the case of metal core plates, because here a thin insulation layer is necessary between the conductor paths 5 and the metal core, which increases the resistance.

Die adhesive is always mentioned in the exemplary embodiments, but alternatively the dies may also be soldered on.

In order to optimize the thermal resistance for high-power applications, the thermal resistances of the individual components should be kept as small as possible.

Here it is to be taken into account that by means of an increase in the area of the components after the transition to the LED carrier, although the thermal resistance decreases linearly, on the other hand with regard to high integration density an increase in size of this area is undesirable for many applications.

It is thus more favorable to optimize the material-specific thermal conductivity of the individual materials or beyond this to select the layer thickness of the components as thin as possible.

The following possibilities are available:

I Use of conductive adhesive d < 10 µm having a conductivity above 1 W/mK

II Use of solder contact layers having thermal conductivity above 20 W/mK and a layer thickness below 30 µm

III Contact area/carrier material

Fundamentally, the following different materials can be used for this purpose:

III.1 Ceramics

Ceramics have a ceramic substrate with thin-layer or thick-layer metallization. In order to discharge the high power densities, preferably AlN or BN are put to use, or AlO is employed in very thin layers.

III.2 Metal Core Boards

Metal core boards are of e.g. Cu or Al. These are provided with non-conducting layers, and conductor paths are then placed thereon (either galvanically or by coating by means of an adhesion/welding method).

The insulation layer may be of either organic material or thin ceramic (the latter e.g. is applied as a slurry onto the metal carrier or applied as a coating using fired ceramic tapes).

In order to further optimize the thermal resistance of the arrangement, non-conducting layers as thin as possible (thinner than 50 µm) are preferably to be put to use. This is fundamentally possible in LED applications, since LEDs typically are operated with a direct current voltage of a few volts, so that there will be no great breakdown field strengths. However, upon handling of the circuit

board, electrical discharges can occur. In order to carry off these electrical discharges, in a preferred variant of the invention the insulator layers of the metal core board are designed to be electrically non-linear such that they are electrically insulating at low voltages (e.g. below 100 V), while they become electrically conducting at high voltages (e.g. above 100 V). Such electrically non-linear materials are known in the state of the art. Alternatively, the LED die can be placed directly on the metal core (Figs. 3 and 5). In this way, the lowest thermal resistances are achieved, and thick insulator layers can be applied without any problem.

The disadvantage of this arrangement is that for the structure in accordance with Fig. 1 special efforts are needed in order to effect electrical contacting via the rear side.

This can be done e.g. by the arrangement of outwardly insulating metal cylinders, which can be contacted from above and below.

III.3 Organic PCBs

In contrast to the variants presented above, the thermal conductivity of the carrier material of an organic PCB is very poor (only 0.1-0.2 W/mK). In order, despite this, to realize sufficient thermal conductivity with these materials, through-contacts, which are at least partially filled with Cu, may be provided in the immediate vicinity of the die. The greater the number of through-contacts, the lower the thermal resistance will be. In order to spread the heat sufficiently for this purpose, metallization layer thicknesses of more than 100 μm, preferably more than 200 μm, are necessary. Typically, these channels have a diameter of

a few tenths of a mm. In an optimized variant the diameter of the channels is only a few micro- or nano-meters. In this manner, a substrate with very high anisotropic electrical and thermal conductivity is realized.

Vienna, 11 July 2003

ABSTRACT

An LED die (3) is arranged with an adhesive (4) on an LED PCB (6). The LED PCB (6) has on the side opposite to the LED die (3) rear side contacts (7). A self-contained LED lamp is thereby formed, which can be e.g. applied by SMT to a board (9) or introduced into a lamp socket. In accordance with the invention, the rear side contacts (7) cover at least half the area, preferably the entire area apart from the necessary exceptions, of the LED PCB (6). The heat can thus be discharged with little thermal resistance. In accordance with another embodiment of the invention, an LED light source has LEDs on a board (9) or on a plug, while the LED dies (3) are pasted with an adhesive (4) directly on the board (9) or on the plug. The LED thus is no longer a self-contained component, but the board (9) or the plug simultaneously assumes the function of the previous LED PCB. Preferably a cooling body (11) is arranged on the rear side of the board (9). In this case it is expedient if the board (9) has through-contacts for increasing the thermal conductivity.

(Fig. 1)

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A1072/2003 Original

16Se/40460

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CLAIMS

1. LED, wherein at least one LED die (3) is arranged on an LED PCB (6) with a die attach (4) and the LED PCB (6) has, on the side opposite to the LED die (3), electrical rear side contacts (7) which if appropriate are formed as plug contacts, **characterized** in that the rear side contacts (7) cover at least half the area, preferably the entire area apart from the necessary exceptions, of the LED PCB (6). (Figs. 1 – 3)

2. LED according to Claim 1, **characterized in** that the rear side contacts (7) are thermally, and if appropriate electrically, connected with the contact areas (conductor paths 5) on the side of the LED PCB (6) towards the LED die, to the lateral side of the LED PCB (6). (Fig. 2)

3. LED according to Claim 1, **characterized in** that the LED PCB (6) is a metal core board and in that the LED die (3) is applied directly onto the metal core. (Fig. 3)

4. LED according to Claim 1, **characterized in** that the LED PCB (6) is a metal

core board and in that there is arranged between the conductor paths and the metal core an electrically non-linear insulator material.

5. LED according to any of Claims 1 – 4, **characterized in** that the LED die *[sic]* is mounted face down on the LED die.

6. LED light source having one or more LEDs according to any of Claims 1 to 5 arranged on a board (9) or on a plug, wherein the board (9) has contact areas (conductor paths 8), or the plug has contacts, with which the LEDs are contacted, **characterized in** that the rear side contacts (7) of the LEDs are soldered with the contact surfaces or with the contacts on at least half the area of the LED PCB, preferably over the entire area apart from the necessary exceptions. (Fig. 1).

7. LED light source having one or more LEDs arranged on a board (9) or on a plug, wherein the board (9) has contact surfaces (conductor paths 5), or the plug has contacts, with which the LEDs are contacted, **characterized in** that the LED dies (3) are pasted with a die attach (4) directly on the board (9) or on the plug. (Figs. 4, 5)

8. LED light source according to Claim 7, **characterized in** that the board (9) is a metal core board and in that the LED dies (3) are applied directly onto the metal core. (Fig. 5)

9. LED light source according to Claim 8, **characterized in** that the board (9) is a metal core plate and in that there is arranged between the conductor paths and the metal core an electrically non-linear insulator material.

10. LED light source according to Claim 6 or 7, **characterized in** that a cooling body (11) is arranged on the rear side of the board (9). (Figs. 1, 4)

11. LED light source according to Claim 10, **characterized in** that the board (9) and/or the LED PCB (6) has through-contacts for increasing the thermal conductivity, wherein the through-contacts preferably have a diameter of less than 100 µm.

Vienna, 11 July 2003